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Berger-Tal, Oded

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Environmental Evidence

SYSTEMATIC REVIEW PROTOCOL

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What evidence exists on the effects of anthropogenic noise on acoustic communication in animals? A systematic map protocol

Oded Berger-Tal[1*], Bob B. M. Wong[2], Ulrika Candolin[3] and Jesse Barber[4]

Abstract

Background: Noise pollution is an intense, widespread anthropogenic disturbance that can have highly detrimental impacts on natural populations, communities, and ecosystems across the globe. One major way through which noise can affect wildlife is by masking acoustic signals that animals rely on and, in doing so, hindering inter- and intraspecific communication among individuals. In response, many animals change their vocal behavior in an attempt to overcome the signal- and cue-masking effects of noisy environments. This can be done by changing the amplitude of the vocal output, shifting its frequency, or changing its temporal structure. However, to date, we still know very little about the ecological contexts of signal modifications in animals or their fitness consequences. We present a protocol for a systematic map aiming to collect and characterize all research done on animals' signal modification in response to anthropogenic noise. The map will increase our understanding of the consequences of noise pollution on animal communication and may guide the development of new mitigation tools to alleviate any negative effects. The map will also allow us to identify gaps in the literature and highlight possible future research areas.

Methods: We will collect information about different types of acoustic modifications in response to noise as well as information about the noise's source and properties. The map will also include the ecological context of the signal modification and the fitness consequences of the modification, if measured. We will search both commercially published literature and grey literature, and conduct the searches in academic journal databases, online search engines, and specialist websites. Articles will be screened for inclusion at title, abstract and full-text levels and will then be critically appraised for study robustness and validity. Data will then be extracted and coded according to categories informed by consultation with stakeholders. Data will be summarized in a quantitative manner, accompanied with a narrative review that will map our knowledge on how animals change their vocalizations in response to noise pollution as a function of their taxa, geographic location, noise pollution source, and vocalization type.

Keywords: Acoustic adaptation, Conservation behavior, Frequency shift, Lombard effect, Noise pollution, Soundscape, Vocal modification

*Correspondence: bergerod@bgu.ac.il
[1] Mitrani Department of Desert Ecology, Ben-Gurion University of the Negev, 8499000 Midreshet Ben Gurion, Israel
Full list of author information is available at the end of the article

Background

Anthropogenic noise has dramatically increased over the last decades as a result of population growth, urbanization, globalization of transportation networks, and expansion of resource extractions [1, 2], making noise an intense, widespread anthropogenic disturbance. A growing body of evidence suggests that this noise may have highly detrimental impacts on natural populations, communities, and ecosystems [3, 4]. Notably, these deleterious effects are not limited to densely populated areas, such as cities, but may also have negative consequences for animal populations in natural, protected areas [5].

Recent reviews have sought to gain mechanistic insights into the direct and indirect effects of noise pollution on animals in order to provide wildlife managers and policy makers with effective mitigation tools [3, 6, 7]. Noise pollution can be directly perceived by animals as a threat, causing them to increase costly anti-predatory behaviors (at the expense of foraging) or to flee the area altogether [8]; noise can distract foragers, reducing their efficiency of finding and handling food [9]; noise may increase physiological stress levels [6]; and noise may have indirect effects, such as scaring away prey or attracting predators [3, 10]. Another major mechanism that has been suggested to drive the deleterious impact of noise pollution on wildlife populations—and which may be particularly disruptive for acoustically communicating species, such as birds, frogs or marine mammals—is interference with signal and cue detection, i.e., masking acoustic communication between individuals or the sounds of an approaching predator or potential prey [3, 11]. Noise can hinder animal communication by reducing the distance at which a signal can be detected [12], limiting the ability of the signal to reach its intended receiver, and decreasing the amount of information that can be extracted from a signal [13, 14]. For example, it has been shown that noise pollution can reduce the ability of birds to collect information on their surroundings, increase their predation risk (by masking the sounds of predators), and interfere with signals that are crucial for their breeding success and parental care (e.g., [3, 15, 16]).

Animals can behaviorally react to anthropogenic noise in various ways, such as by moving away from the source of the noise (either temporarily or permanently), temporally adjusting their own activities to avoid the noisiest times of the day, or increasing their anti-predator behavior [3]. In addition, many animals change their vocal behavior in an attempt to overcome the cue-masking effects of the noisy environment (both natural and anthropogenic) [1]. The most noticeable vocal adjustments made by animals are: (i) changing the amplitude of the call (the Lombard effect, [17, 18]); (ii) shifting the frequency of the call [19, 20]; (iii) changing the temporal structure of the call (timing of modulations, notes, and syllables within the calls, [21]); and (iv) altering the timing of the call delivery (e.g., changes to the repetition rates of the call).

While there is already considerable evidence on how animals modify their vocalizations in response to anthropogenic noise, we still have large gaps in our knowledge. So far, most reviews or studies on signal modification in response to noise pollution seem to have mostly ignored the grey literature on the subject and have focused almost exclusively on one type of modification (such as changes to amplitude, or changes to frequency) even though the probable interactions among the different call components are likely to be important [22]. Moreover, the ecological context of the calls has often been ignored, which may have created a bias towards some type of calls (e.g., territorial or mating calls) over others (e.g., parent–offspring calls or alarm calls) [21, 23]. Lastly, we know very little about the fitness consequences of signal modifications. On the one hand, these modifications are a supposedly adaptive response to the masking effect of noise. On the other, they can impose various fitness costs, such as increasing the energetic demands on the caller, and reducing the effectiveness of the call itself by reducing the ability of conspecifics to effectively detect and respond appropriately to the signal [21]. This has led many researchers to pinpoint the fitness effects of signal modifications as a vital avenue for future research (e.g., [20, 21, 23]). The following protocol for a systematic map aims to address the abovementioned needs and limitations of the current state of evidence.

Stakeholder engagement

Understanding the fitness consequences of signal modification due to noise pollution was raised as a top priority among wildlife managers and behavioural ecologists during a recent international workshop designed to develop the first set of discipline guidelines for using evidence synthesis as a tool for applying animal behaviour research to management and policy [24]. We contacted relevant stakeholders both from within (behavioral ecologists, conservation biologists, sensory ecologists), and outside of, (birders, wildlife managers, and conservation biologists from various birding or conservation organizations) academia (Additional file 1), and asked them for information about the topic, as well as for their advice regarding important avenues for investigation. We used the stakeholders input to define the scope of the evidence synthesis, identify relevant data-bases for our searches, and refine the search terms.

Objectives

We aim to systematically map all research done on acoustic signal modification in response to anthropogenic noise by all animals in both terrestrial and marine environments. We will consider all types of signal modifications: changes in amplitude, frequency, temporal structure, and phenology of any type of vocalization (e.g., courtship calls, territorial calls, alarm calls, etc.). The resulting map will increase our understanding of the consequences of noise pollution on animal communication and may guide the development of new mitigation tools to alleviate any negative effects. The map will also allow us to identify gaps in the literature and highlight possible future research areas.

Primary question

How do animal modify their vocalizations in response to anthropogenic noise?

Components of the primary question

Population All animal species.
Exposure Anthropogenically produced noise (regardless of its source).
Outcome Changes to the amplitude, frequency, temporal structure, and phenology (timing) of any type of vocalizations.
Comparator Animals not exposed to anthropogenic noise.

Methods

The map protocol follows CEE guidelines [25] and complies with the ROSES reporting standards (Additional file 2).

Searching for articles

Languages

All searches will be conducted using English search terms, but no restriction will be placed on result language. We will aim to find translators for any relevant article (or report) written in a language other than English that will pass through all screening stages (the authors themselves are able to translate results from Hebrew, Spanish, Swedish, Norwegian, Danish, Finnish, German, and French).

Search string

We conducted a scoping exercise in Web of Science in which we tested the impact of adding or modifying relevant keywords in terms of the number of papers added to the search results and their relevance. We also chose three key reviews [18, 20, 21] on the subject and checked whether the keywords successfully returned the reviews and a selection of their key references (Additional file 3). We will use the search string using Boolean operators which will be modified in accordance with the specific database we will be searching. The search string keywords represent the exposure (anthropogenic noise) and the outcome of the primary question (change in vocalization). Population and comparator will be screened from the results (i.e. studies focusing on the effects of noise on humans or that have no comparator will be excluded). All searches will be conducted using Ben-Gurion University's institutional subscription. In cases when this subscription will not provide access to the full text of an article, we will use one of the other authors' university subscriptions, or contact the paper's author directly. The search string is as follows (in a Web of Science format):

Exposure: ts=(noise OR acoust* OR soundscape*) AND (pollut* OR artificial* OR anthropogen* OR urban OR disturb* OR *sonar OR "air gun*" OR vehicle* OR road* OR transportation OR *plane* OR turbine* OR ship* OR broadcast OR playback OR "white noise")

AND

Outcome: ts=(signal* NEAR/3 modif*) OR (signal* NEAR/3 change*) OR (signal* NEAR/3 alter*) OR (signal* NEAR/3 shift*) OR (signal* NEAR/3 modulat*) OR (signal* NEAR/3 increas*) OR (signal* NEAR/3 decreas*) OR (call* NEAR/3 modif*) OR (call* NEAR/3 change*) OR (call* NEAR/3 alter*) OR (call* NEAR/3 shift*) OR (call* NEAR/3 modulat*) OR (call* NEAR/3 increas*) OR (call* NEAR/3 decreas*) OR (song* NEAR/3 modif*) OR (song* NEAR/3 change*) OR (song* NEAR/3 alter*) OR (song* NEAR/3 shift*) OR (song* NEAR/3 modulat*) OR (song* NEAR/3 increas*) OR (song* NEAR/3 decreas*) OR (vocal* NEAR/3 modif*) OR (vocal* NEAR/3 change*) OR (vocal* NEAR/3 alter*) OR (vocal* NEAR/3 shift*) OR (vocal* NEAR/3 modulat*) OR (vocal* NEAR/3 increas*) OR (vocal* NEAR/3 decreas*) OR (whistle* NEAR/3 modif*) OR (whistle* NEAR/3 change*) OR (whistle* NEAR/3 alter*) OR (whistle* NEAR/3 shift*) OR (whistle* NEAR/3 modulat*) OR (whistle* NEAR/3 increas*) OR (whistle* NEAR/3 decreas*) OR (frequency NEAR/3 modif*) OR (frequency NEAR/3 change*) OR (frequency NEAR/3 alter*) OR (frequency NEAR/3 shift*) OR (frequency NEAR/3 modulat*) OR (frequency NEAR/3 increas*) OR (frequency NEAR/3 decreas*) OR (amplitude NEAR/3 modif*) OR (amplitude NEAR/3 change*) OR (amplitude NEAR/3 alter*) OR (amplitude NEAR/3 shift*) OR (amplitude NEAR/3 modulat*) OR (amplitude NEAR/3 increas*) OR (amplitude NEAR/3 decreas*) OR "signal* plasticity" OR "call* plasticity" OR "song* plasticity" OR "vocal* plasticity" OR lombard OR "acoustic adaptation" OR "frequenc* shift*" OR phenolog* OR "nocturnal sing*" OR "nocturnal call*" OR "evoked vocal response*")

When possible, the search will be limited to journals on the broad topics of biology (including ecology and zoology), environmental sciences, urban studies, acoustic, and multidisciplinary studies.

Abbreviated search

Where a complex search string is not accepted, searches will aim to include at least one term for exposure and one for outcomes. All modified search strings will be recorded.

Estimating comprehensiveness of search

To evaluate the performance of the search strategy, we compared the results of our search with a test list of 42 articles compiled from three recent published reviews on different specific signal modifications in response to anthropogenic noise (i.e., changes in amplitude, changes in frequency) [18, 20, 21]. The search string was then amended and tweaked to maximize the inclusion of relevant papers. Following the search, six papers were found to be not relevant for the map's topic. Out of the remaining 36 articles, the final search yielded 27. The missing nine were articles without abstracts (an inherent bias of the search in ISI); however going over these papers revealed that in all of them, our keywords were found in the text, and thus they are expected to come up in a one of the searches in the other databases.

Publication databases

The search will be conducted using the following online databases:

- ISI Web of Science Core Collection
- Scopus
- JSTOR
- PubMed
- Agricola
- Environmental Sciences and pollution management
- Sustainability science abstracts
- Wiley Online Library
- BioOne
- WildPro Electronic Library
- ProQuest

Internet searches

The following search engine will also be used for finding studies (we will include only the first 200 search results):

- Google Scholar (https://www.GoogleScholar.com)

Specialist sources

Websites of the following organizations will be searched for any relevant literature.

- IUCN general publications (https://portals.iucn.org/library/dir/publications-list).
- IUCN Conservation Planning Specialist Group (http://www.cpsg.org/document-repository).
- Conservation Evidence (https://www.ConservationEvidence.com).
- US Federal Science database (https://www.science.gov/).
- National Parks Service (https://www.nps.gov/).
- US Fish & Wildlife Service (http://www.fws.gov/).
- Wildlife Conservation Society (http://library.wcs.org/).

All methods of retrieval for grey literature will be documented and presented in a supplementary file for the final publication.

Article screening and study eligibility criteria

Study screening process

We will conduct the screening process through the online open source platform of CADIMA (https://www.cadima.info/). CADIMA's platform facilitates extraction of articles, removal of duplicate studies, a three-stage screening process (at the title, abstract, and full text levels), and measuring inter-screener reliability. Review articles will not be included, but their reference lists will be checked to ensure that all relevant literature they cover is included in our searches.

We will use CADIMA's three-stage screening process to evaluate all articles found using our search string. First, we will evaluate the articles' relevance based on their title, with those deemed outside the scope of the review excluded from further evaluation stages. To check consistency, a subset of 200 article titles or 10% (whichever is greater) will be assessed by an additional reviewer (i.e. by a total of two reviewers chosen from the authors of this protocol). Cohen's kappa coefficient will be calculated to determine the level of agreement between the two reviewers and a value above 0.6 will indicate adequate consistency. In case of inconsistency, discrepancies will be discussed and the inclusion criteria will be clarified or modified. Second, we will repeat the process for all articles that have passed the title stage, reading their abstract to assess their relevance. Lastly, we will evaluate the relevance of all studies identified as relevant at the abstract and title stages by studying their full text. Full texts will be retrieved via open source platforms and institutional access where possible. If the full text of a given study cannot be found through those means, authors will be contacted to request a copy. Any reviewer who is the author of a study will not decide on the inclusion of that study and, in cases of uncertainty, the reviewer will err towards inclusion.

At the third stage, a subset of 20 articles or 10% (whichever is greater) will be assessed by two different reviewers. As in stage one, Cohen's kappa coefficient will be calculated to determine the level of agreement between reviewers and a value above 0.6 will indicate adequate consistency. In case of inconsistency, discrepancies will be discussed and the inclusion criteria will be clarified or modified. In cases where there is uncertainty about the relevance of a study, the reviewers will lean towards inclusion. All articles screened at full text that are excluded will be recorded with the reason as to why they are excluded.

Eligibility criteria

For an article to be included it must fulfil the following criteria:

> *Eligible subjects* Any animal or group of animals (excluding humans).
> *Eligible exposure* Anthropogenically produced noise, regardless of its source (e.g., roads, urban environment, industry, etc.)
> *Eligible outcomes* The study must report changes to the amplitude, frequency, temporal structure, or phenology of any type of vocalizations by the subject animals in response to the anthropogenic noise.
> *Eligible comparator* The study must compare between the vocal behavior of individuals that are exposed to anthropogenic noise and individuals that are not exposed to anthropogenic noise.

Study validity assessment

All studies that pass the full-text screening stage will undergo a critical appraisal of the quality and validity of the study on a 1–5 scale (1 being the lowest quality, and 5 being the highest) for the following parameters:

- Study design (a score of 1 representing observational study, and a score of 5 representing a Before-After-Control-Impact (BACI) study design).
- Replication (a score of 1 representing no replication, and a score of 5 representing over 6 replications).
- Study setting (a score of 1 representing a closed laboratory setting, a score of 5 representing a field study, and intermediate scores representing semi-natural laboratory conditions).
- The temporal extent of the study (a score of 1 representing a study conducted over several days only, and a score of 5 representing a study taking place over an entire season or even multiple seasons).

Whenever information on the study design or results is unclear from the text, we will contact the authors directly and ask them for the information. The overall quality of the study will be determined by the average score across the parameters. To ensure repeatable estimation of quality, a subset of 10% of studies will be assessed by two reviewers (chosen, as before, from the authors of this protocol). Any reviewer who is the author of a study will not decide on the ranking of that study and any disagreement between the reviewers will be solved through discussion and, if necessary, consultation with a third reviewer.

Data coding and extraction strategy

We will extract descriptive data from all studies meeting our inclusion criteria. All data extracted will be coded and recorded in an Excel spreadsheet.

Extracted information will include:

- Date of data extraction
- Animal species
- Sex composition
- Age composition
- Life history stage
- Study location
- Study date (season, year)
- Study setting (lab/field)
- Study design (observational, BA, CI, BACI)
- Source of anthropogenic noise
- Properties of anthropogenic noise (when available)–intensity (dBA), frequency (Hz), and temporal structure
- Acoustic metric used to measure vocalizations
- Sample size
- Type of change(s) in vocalization (Amplitude, frequency, temporal structure)
- Call type (e.g., territorial call, mating call, alarm call)
- Mean level of recorded change
- Measures of variation such as standard error, standard deviation and confidence intervals
- Fitness outcomes of signal modification (if available)
- Any other recorded behavioral changes in response to anthropogenic noise (if available)

If relevant data are not easily decipherable, we will seek the data in online data repositories or, when needed, contact the lead and corresponding authors via e-mail and ask for the missing data or information.

To ensure that data are extracted in a way that is repeatable and consistent, two reviewers will extract information from a subset of 10% of articles. Any inconsistencies in the extracted information will be discussed and the extraction methodology refined.

Study mapping and presentation

We will synthesize the data from all included studies into a narrative review. The narrative review will be accompanied by at least four heat maps in which we will quantify the relative number of studies on changes to the vocalization behavior of animals in response to noise pollution as a function of the taxa of the subject animals, the geographic location of the study (i.e., creating an atlas of the available evidence on the subject), the noise pollution source, and the vocalization type (i.e. whether it is a mating call, and alarm call, or some other call). These heat maps will serve us to recognize knowledge gaps and knowledge clusters. We will further synthesize each knowledge cluster to analyze the vocalization modification types that have been studied (and whether more than one type of modification has been studied in the same species or system), and the quality of the analysis (in terms of study design and statistical robustness). In addition to the narrative synthesis and the heat maps, the full Excel spreadsheet with all the extracted data coded will be made available for download.

Additional files

Additional file 1. List of stakeholders contacted.

Additional file 2. ROSES form.

Additional file 3. List of benchmark studies used to create search string.

Abbreviations

BA: A before/after experimental design. An experimental design that compares parameter values before and after a particular treatment or disturbance; CI: A control/intervention experimental design. An experimental design that compares parameter values between groups that have been exposed to a certain intervention and control groups that have not been exposed to the intervention; BACI: A before/after, control/intervention experimental design, which combines the two prior study designs.

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Authors' contributions

OB-T wrote the first draft of the paper. All authors contributed to the writing of the final draft. All authors read and approved the final manuscript.

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Availability of data and supporting materials

No datasets were generated or analyzed during the preparation of the protocol. All data that will be used for the review will be made freely available upon the publication of the review.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1] Mitrani Department of Desert Ecology, Ben-Gurion University of the Negev, 8499000 Midreshet Ben Gurion, Israel. [2] School of Biological Sciences, Monash University, Victoria 3800, Australia. [3] Department of Biosciences, University of Helsinki, 00014 Helsinki, Finland. [4] Department of Biological Sciences, Boise State University, Boise, ID 83725, USA.

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References

1. Shannon G, McKenna MF, Angeloni LM, Crooks KR, Fristrup KM, Brown E, et al. A synthesis of two decades of research documenting the effects of noise on wildlife. Biol Rev. 2016;91:982–1005.
2. Sordello R, De Lachapelle FF, Livoreil B, Vanpeene S. Evidence of the environmental impact of noise pollution on biodiversity: a systematic map protocol. Environ Evid. 2019;8:8.
3. Francis CD, Barber JR. A framework for understanding noise impacts on wildlife: an urgent conservation priority. Front Ecol Environ. 2013;11:305–13.
4. Swaddle JP, Francis CD, Barber JR, Cooper CB, Kyba CCM, Dominoni DM, et al. A framework to assess evolutionary responses to anthropogenic light and sound. Trends Ecol Evol. 2015;30:550–60.
5. Buxton RT, McKenna MF, Mennitt D, Fristrup K, Crooks K, Angeloni L, et al. Noise pollution is pervasive in US protected areas. Science. 2017;356:531–3.
6. Kight CR, Swaddle JP. How and why environmental noise impacts animals: an integrative, mechanistic view. Ecol Lett. 2011;14:1052–61.
7. Blumstein DT, Berger-Tal O. Understanding sensory mechanisms to develop effective conservation and management tools. Curr Opin Behav Sci. 2015;6:13–8.
8. Ware HE, McClure CJW, Carlisle JD, Barber JR. A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. Proc Natl Acad Sci USA. 2015;112:12105–9.
9. Chan AA, Giraldo-Perez YH, Smith P, Blumstein DT. Anthropogenic noise affects risk assessment and attention: the distracted prey hypothesis. Biol Let. 2010;6:458–61.
10. Bunkley JP, McClure CJW, Kawahara AY, Francis CD, Barber JR. Anthropogenic noise changes arthropod abundances. Ecol Evol. 2017;7:2977–85.
11. Barber JR, Crooks KR, Fristrup KM. The costs of chronic noise exposure for terrestrial organisms. Trends Ecol Evol. 2010;25:180–9.
12. Slabberkoorn H, Peet M. Ecology: birds sing at a higher pitch in urban noise. Nature. 2003;424:267.
13. Read J, Jones G, Radford AN. Fitness costs as well as benefits are important when considering responses to anthropogenic noise. Behav Ecol. 2014;25:4–7.

14. Rosa P, Koper N. Integrating multiple disciplines to understand effects of anthropogenic noise on animal communication. Ecosphere. 2018;9:e02127.
15. Halfwrek W, Holleman LJM, Lessells CM, Slabbekoorn H. Negative impacts of traffic noise on avian reproductive success. J Appl Ecol. 2011;48:210–9.
16. Schroeder J, Nakagawa S, Cleasby IR, Burke T. Passerine birds breeding under chronic noise experience reduced fitness. PLoS ONE. 2012;7:e39200.
17. Junqua JC, Fincke S, Field K. 1999. The Lombard effect:a reflex to better communicate with others in noise. In: IEEE International Conference Acoustics, speech, and signal processing conference proceedings. 1999. Phoenix, AZ: IEEE Vol. 4, p. 2083–6.
18. Hotchkin C, Parks S. The Lombard effect and other noise-induced vocal modifications: insight from mammalian communication systems. Biol Rev. 2013;88:809–24.
19. Potvin DA, Mulder RA. Immediate, independent adjustment of call pitch and amplitude in response to varying background noise by silvereyes (*Zosterops laterallis*). Behav Ecol. 2013;24:1363–8.
20. Roca IT, Desrochers L, Giacomazzo M, Bertolo A, Bolduc P, Deschesnes R, et al. Shifting song frequencies in response to anthropogenic noise: a meta-analysis on birds and anurans. Behav Ecol. 2016;27:1269–74.
21. Patricelli GL, Blickley JL. Avian communication in urban noise: causes and consequences of vocal adjustment. Auk. 2006;123:639–49.
22. Brumm H, Bee MA, et al. A meta-analytic castle built on sand? A comment on Roca et al. Behav Ecol. 2016;27:1275–9.
23. Wong BBM, et al. The struggle to be heard in an increasingly noisy world: a comment on Roca et al. Behav Ecol. 2016;27:1275–6.
24. Greggor AL, Berger-Tal O, Blumstein DT, Angeloni L, Bessa-Gomes C, Blackwell BF, et al. Research priorities from animal behaviour for maximising conservation progress. Trends Ecol Evol. 2016;31:953–64.
25. Collaboration for Environmental Evidence. 2018. Guidelines and Standards for Evidence synthesis in Environmental Management. Version 5.0 (Pullin AS, Frampton GK, Livoreil B, Petrokofsky G, Eds) www.environmentalevidence.org/information-for-authors. Accessed 2 April 2019.

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